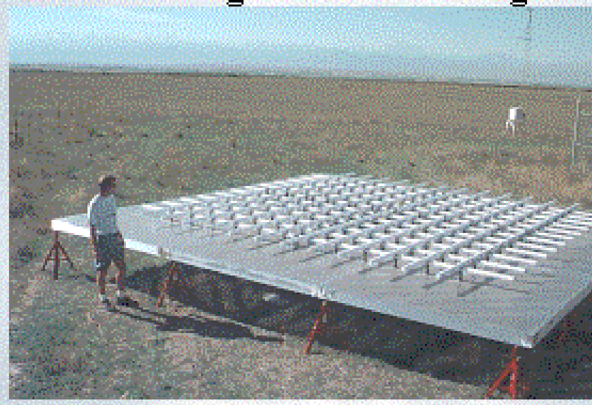
U.S. Department of Energy

Brookhaven National Laboratory

Global Change Education Program



Determining Cloud Structure Using Wind Profiler (449MHZ) Data

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Prologue

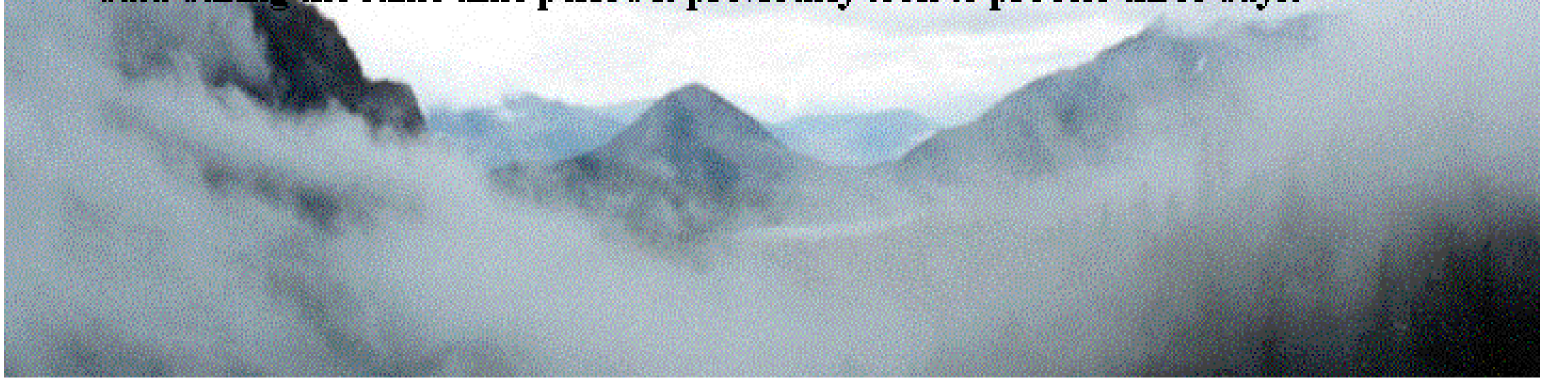
❖The Earth System Science Division (ESSD) supports DOE activities through basic and applied research in ecology, marine science, biogeochemistry, microbiology, and plant physiology. ESSD efforts are focused on developing the means of evaluating and resolving environmental problems associated with energy production and use.

❖ESSD develops specialized plant exposure systems such as the Free-Air Carbon Dioxide Enrichment program. This program seeks to gain an understanding of the role of ecosystems by regulating global carbon dioxide concentrations.

❖ESSD also conducts basic research and devises technologies to increase the understanding of global climate change. As participants in the DOE Atmospheric Radiation Measurement (ARM) Program, they seek to understand the effects of clouds in the earth's overall radiation budget. The sites in which these studies are performed are located in the Southern Great Plains, the Tropical Western Pacific, and the North Slope of Alaska.

Abstract

Clouds play a significant role in regulating climate. They are associated with most significant weather events, as well as fluxes of incoming and outgoing radiation. Therefore, it is necessary to gain a detailed understanding of all cloud types and their impact on the radiation budget of the planet. A potential new method for obtaining cloud data is a 449MHz wind profiler. To evaluate this new technique, data is compared with that from a 94 GHz cloud radar, a standard cloud measuring system. If successful, the 449 MHz wind profiler is a more cost effective method for measuring cloud structure. In order to prove this hypothesis, the data was collected from radars and placed in files of Netcdf format. Computer codes necessary to process these data must be highly efficient due to the large size of the data set. Existing codes were too inefficient to process data from long time periods (years). The efficiency of the existing codes were improved by 12,000%, as a result of this project. With this new code, it is now possible to process an entire year's worth of wind profiler data during the same time period it previously took to process three days.



Scientific Objectives

Prove that cloud structure can be successfully measured with

449MHz Wind Profiler Radar by:

- **Using temporal and spatial statistics.**
- **Comparing it with the 94GHz cloud profiling radar at the central facility.**

Wind Profiler

What is a Wind Profiler?

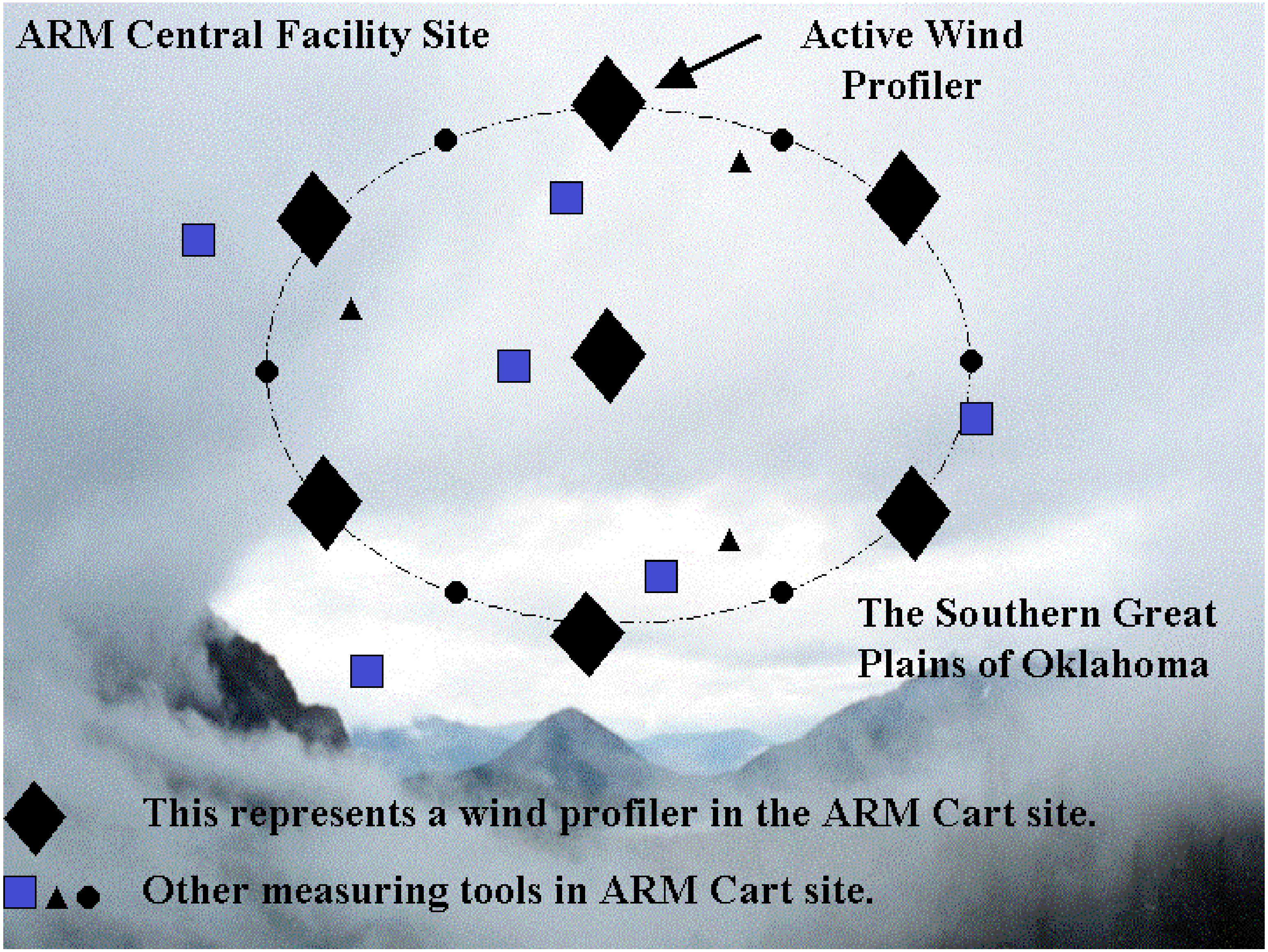
- A wind profiler describes the speed and direction of air as a function of height. The target detected by a wind profiler is atmospheric turbulence. A wind profiler is the operational application of a radar originally developed by scientists for measuring the echo intensity and the wind profile up to about 30km with height resolutions from 100 to 1500m. Winds are measured continuously (6 min. resolution).

How does it measure cloud structure?

- It detects and measures the vertical profile of the enhanced backscattered power within clouds, relative to the lesser backscattered power in the quiescent surrounding clear air. This information, combined with measurements collected from other instruments would be used to derive the vertical and horizontal structure of cloud fields on a global scale and help the understanding of climate mechanisms.

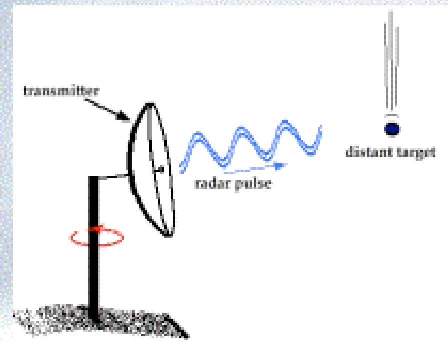
Can a wind profiler measure cloud structure as accurately as a 94 GHz cloud radar, but at a significantly reduced cost?

- The purpose of this project is to answer the above question. The wind profiler is more cost effective than a 94GHz cloud radar; system costs are 1.5 million vs. 300,000 dollars. In some instances it is possible that using turbulence from the wind profiler may be a more precise measuring tool than measuring cloud droplets with the 94GHz cloud radar to identify the location of clouds.

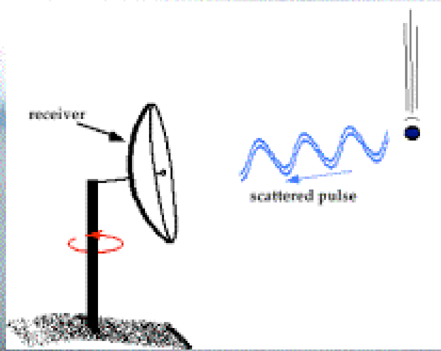

ARM Central Facility Site
Active Wind Profiler
The Southern Great Plains of Oklahoma
This represents a wind profiler in the ARM Cart site.
Other measuring tools in ARM Cart site.

How Is the Data Received?

- First, a pulse is transmitted from the radiometer into the atmosphere.
- The pulse hits a target at a particular range gate.

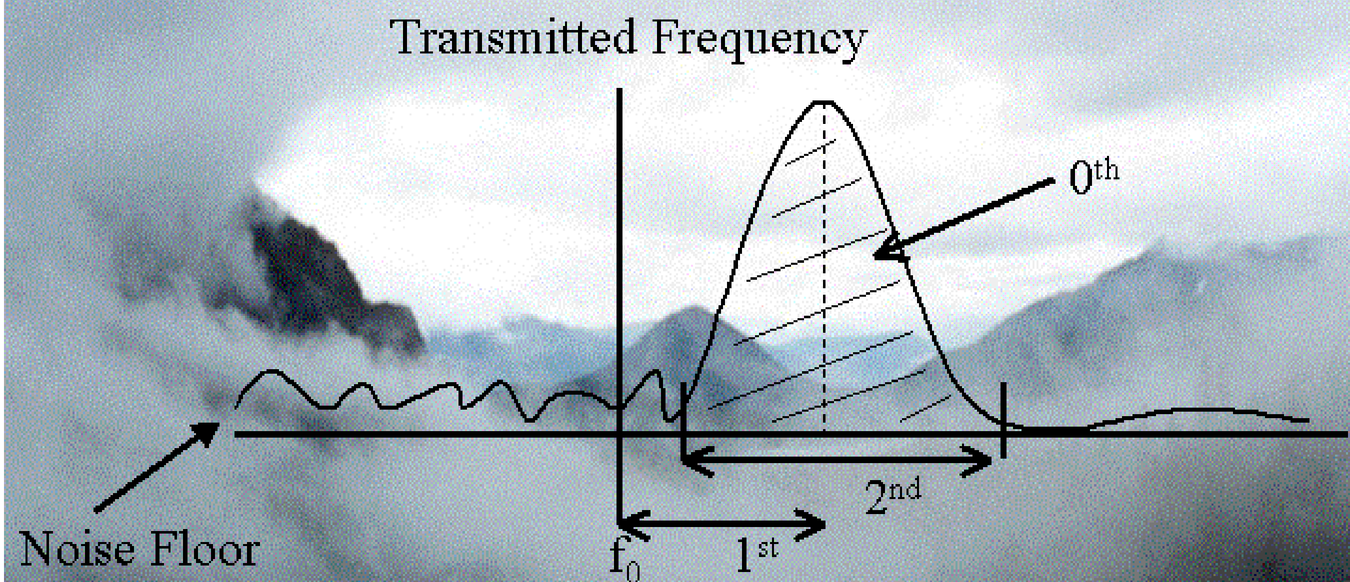


- Then the pulse is scattered back and processed into the receiver



What Kind of Data is Received?

- Three moments are taken into account in measuring the structure of clouds:
  - The 0^{th} moment, the area below the pulse curve,
  - The 1^{st} moment, the phase shift distance,
  - And the 2^{nd} moment, the width of the pulse curve.



Methods and Materials

The best way to describe the methods and materials used is to start with a brief introduction to the powerful MATLAB language. MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

MATLAB is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar non-interactive language such as C or Fortran.

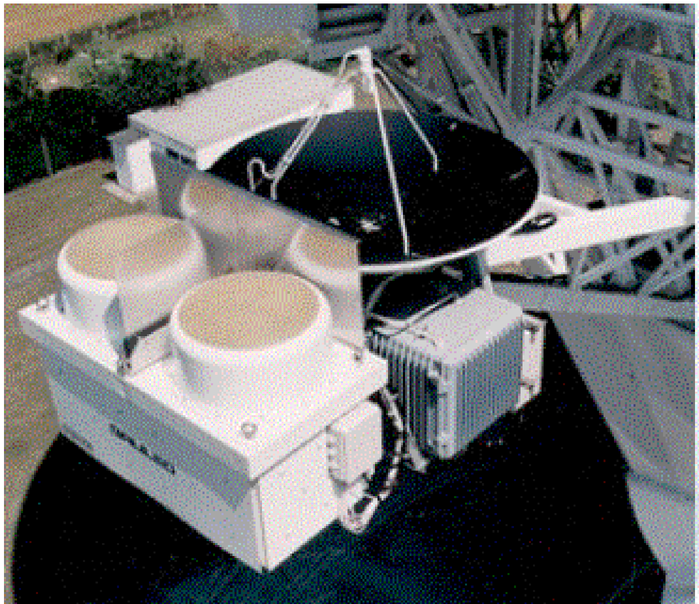
The name MATLAB stands for *matrix laboratory*. MATLAB has evolved over a period of years with input from many users. In university environments, it is the standard instructional tool for introductory and advanced courses in mathematics, engineering, and science. In industry, MATLAB is the tool of choice for high-productivity research, development, and analysis.

MATLAB was used to write an algorithm to evaluate and access huge data collected by the 449 MHz wind profiler radar. The project began by downloading the netcdf files and toolbox for the months of June and July 1997. Each file mostly contains 6 hours of data taken from the receiver. Five files contain the data for one day. The objective is to combine these five files as one file. After concatenating the five files,the files were concatenated into two months worth of data and eventually into years.

Results

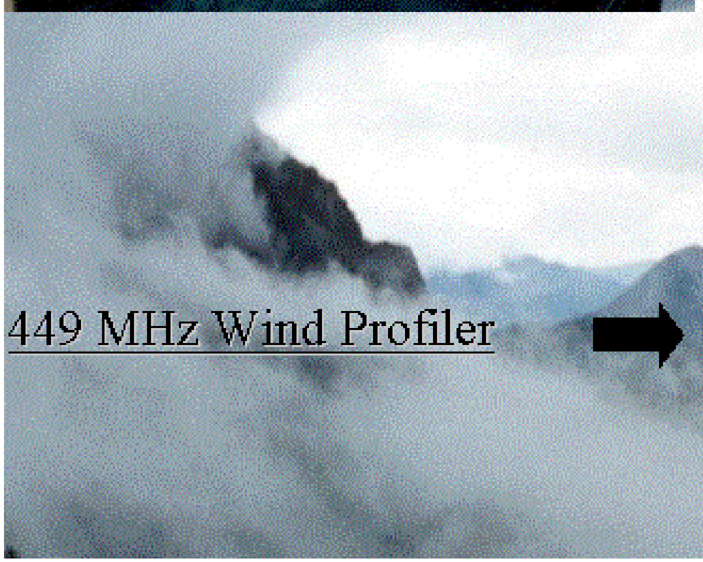
Approximately two weeks were spent on studying and learning the MATLAB language. Becoming familiar with the language was crucial to implementing a quick, capable program.

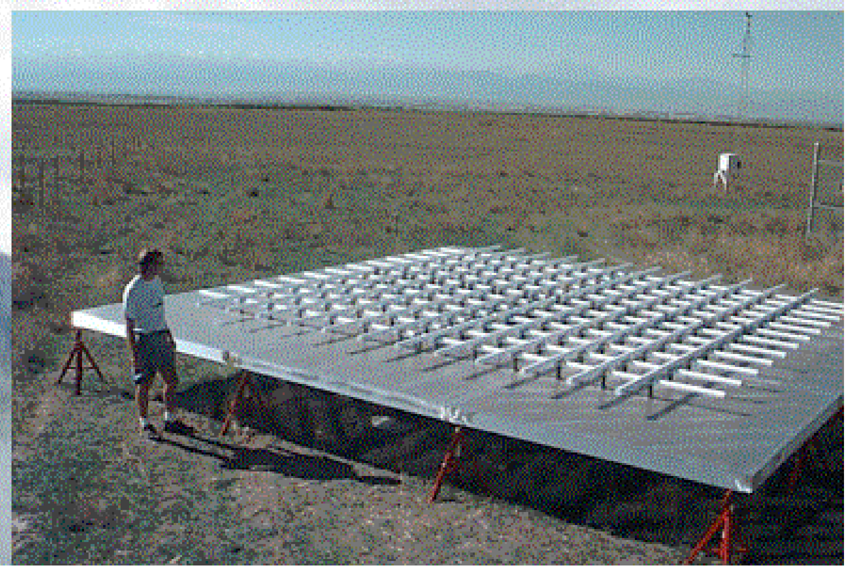
The best way to write an efficient program was to feed the Netcdf (Network communication data format) files, as data was collected from the 449MHz wind profiler radar, through a MATLAB script. Successfully, the program concatenated the five files allotted for each day. The program also allows for days to be combined into months, and months into years. Another attribute about the program is that it allows for days that have less than five files per day of data to be concatenated. The time the program takes to process the data is 120 times more efficient than the original program we started with. With results like this, one can evaluate a whole year's worth of data in about an hour and 30 minutes.



94 GHz Galileo Cloud Radar

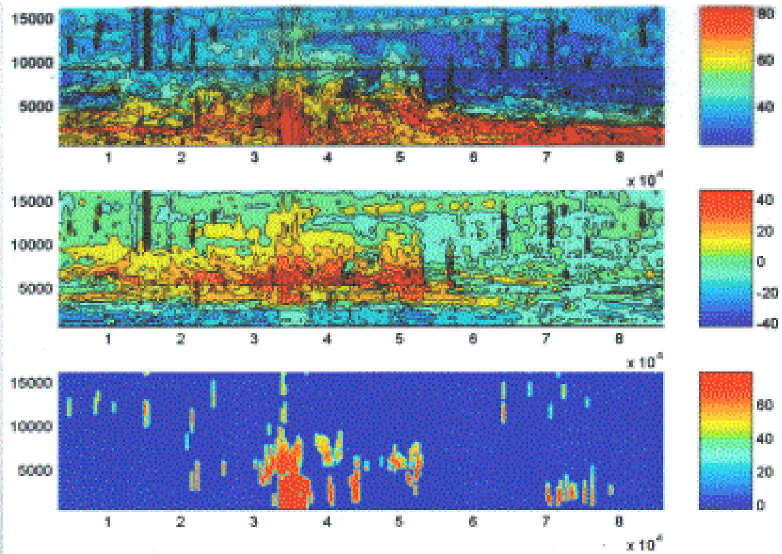
Radar type: BISTATIC
Frequency: 94.00 GHz
Antenna diameter: 0.6 meters
Peak power: 1.6 kW
Pulse width: 0.5 µs
PRF: 6250 Hz
System noise figure: 10 dB
Beam width: 0.5°
Max.range resolution: 60 meters
Noise at 1 km: -36.0 dBZ

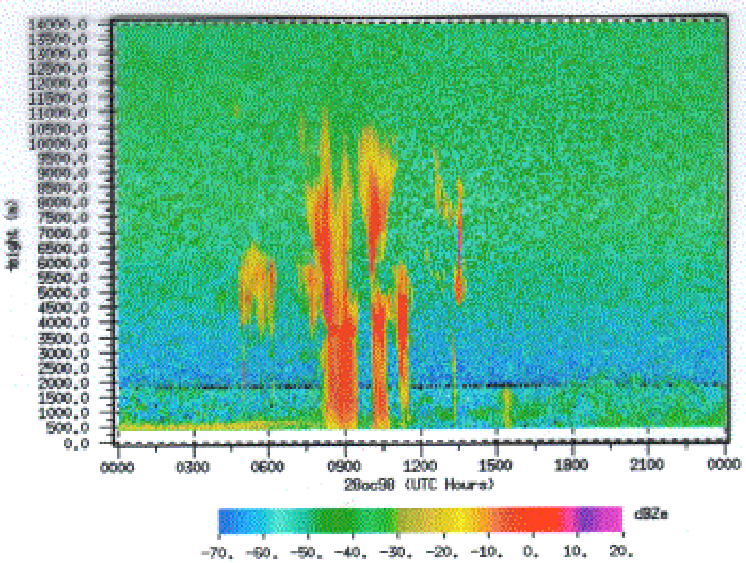




449 MHz Wind Profiler Data

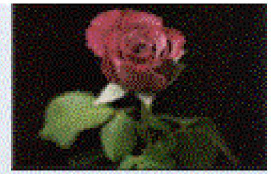
Graph 1. Taken in the summer of 1998 using 449MHz wind profiler radar.





94 GHz Cloud Radar Data

Graph 2. Taken in the summer of 1998 using 94 GHz wind profiler radar.



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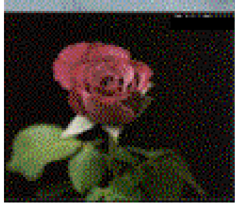

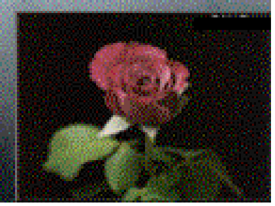

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System Demonstration and Integration Division

(http://www4.etl.noaa.gov/tech/).

The Met. Office

(http://www.met-office.gov.uk/sec5/CWINDED/cwinde99/profilers.html).